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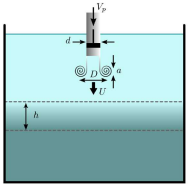
To cite this version:

Albagnac, Julie  and Léard, Pierre and Anne-Archard, Dominique  and Brancher, Pierre  and Pinaud, Johan  and Cazin, Sébastien  and Rida, Zeinab  *Dynamics of an inclined Vortex Ring interacting with a density stratification*. (2019) In: Environmental Fluid Dynamics: Confronting Grand Challenges, 20 January 2019 - 25 January 2019 (Les Houches, France). (Unpublished) .

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DYNAMICS OF AN INCLINED VORTEX RING INTERACTING WITH A DENSITY STRATIFICATION

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Johan PINAUD, Sébastien CAZIN, Zeinab RIDA (UMR 5502)



$$h = 1.5d$$

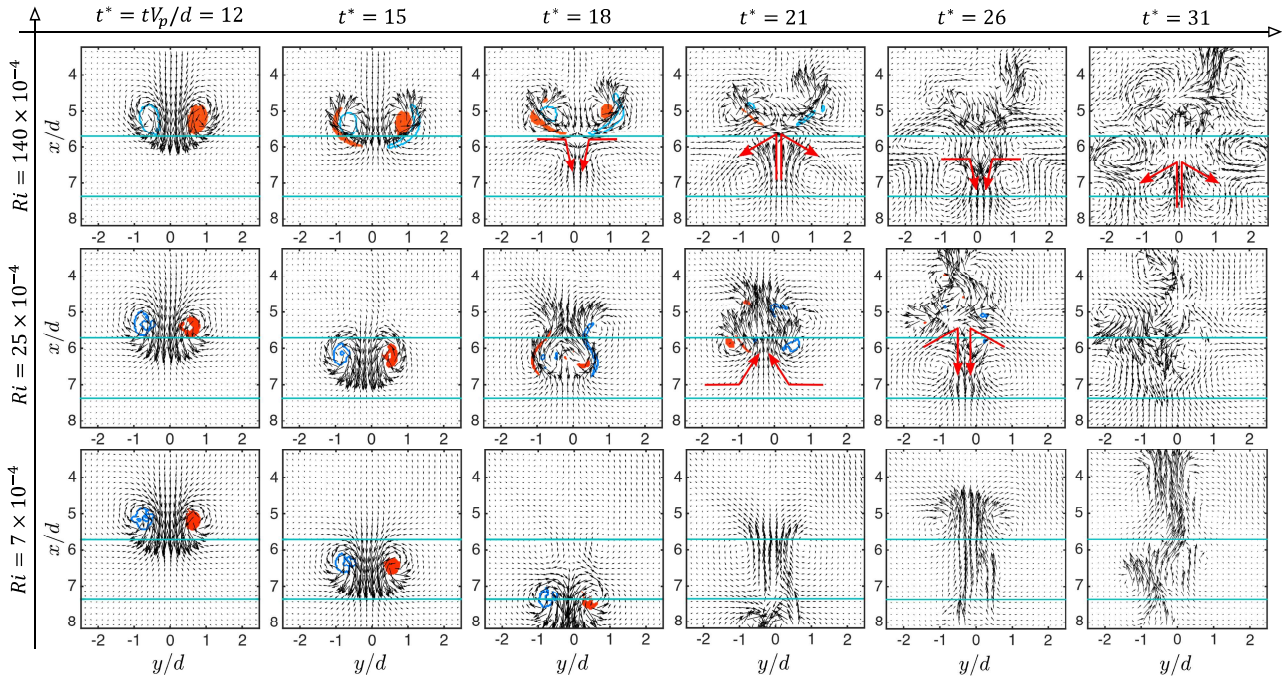
$$At = \frac{\rho_2 - \rho_1}{\rho_1 + \rho_2} \sim 0.03$$

$$N = \left(\frac{2g}{h} At \right)^{1/2} = 1.7s^{-1}$$

$$Fr = \frac{V_0}{Nd} = [0.83, 1.94, 3.74]$$

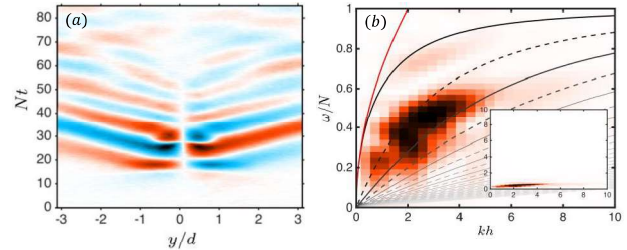
$$Ri = \frac{At}{Fr^2} = [7.25, 140] \times 10^{-4}$$

Abstract: Vortex rings are coherent vortical structures that dominate the dynamics of numerous flows as they are generated each time an impulsive jet occurs in a homogeneous fluid (for instance, plumes can be considered as vortex rings). Such structures have the faculty to self-propagate along their revolution axis, conferring them capacities of transport and mixing that could be exploited. Among applications, one can mention nuclear safety and the need to mix fluids of different density to prevent explosion hazard. The scope of the present study is to identify and evaluate the mixing mechanisms associated with a vortex ring interacting with a density stratification, in particular, the reorganization of the flow and the generation of internal waves. The influence of the vortex ring propagation speed and propagation angle relative to the density gradient on its dynamics and mixing power are studied thanks to 2D and 3D time-resolved TOMO-PIV.

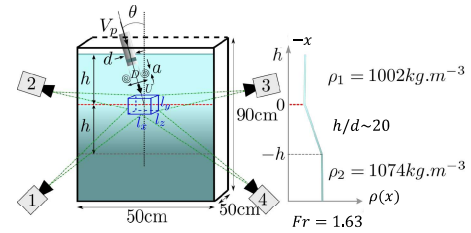
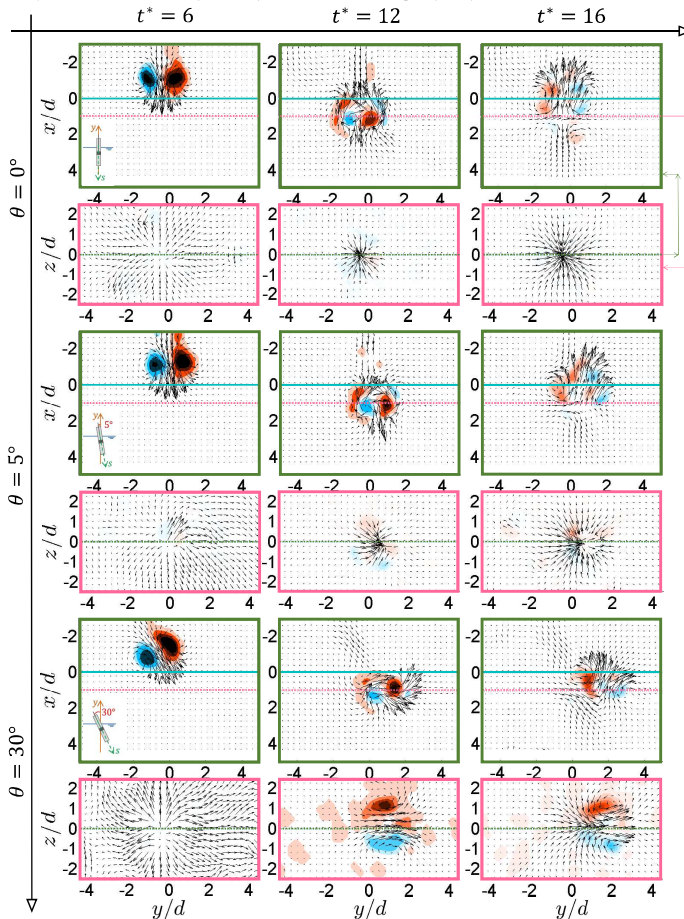


Vortex ring vertical symmetry plane: Velocity (black arrows) and horizontal vorticity contours (positive red and negative blue) fields at several times (columns) for several Richardson numbers (rows). Blue lines point upper and lower boundaries of the linear stratification.

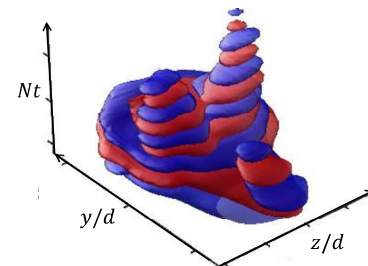
Vortex ring vertical symmetry plane in green frames: Velocity (black arrows) and horizontal vorticity contours (positive red and negative blue) fields at several times (columns) for several attack angles (rows). Horizontal plane $1d$ under the stratification upper boundary in pink frames: Velocity (black arrows) and vertical vorticity contours (positive red and negative blue) fields at several times (columns) for several attack angles (rows).



(a) Spatio-temporal diagram of the spanwise velocity at the stratified layer mid-depth for $Ri = 140 \times 10^{-4}$. (b) FFT of (a) in space and time (color) and theoretical internal waves dispersion curves (grey curves).



TOMO-PIV system:
- laser Photonics ($2 \times 60mJ$, $527nm$, $L_x \times L_y \times L_z = 30 \times 20 \times 10cm^3$)
- 4 cameras SC CMOS ($f = 150Hz$, $2560 \times 2160 pix$)
- fluorescent particles ($\emptyset 30 \mu m$, $\rho_p = 1050 kg.m^{-3}$, $N_p \sim 2 \times 10^4$ part. during 1s)



3D spatio-temporal diagram of the vertical velocity $1d$ under the stratification upper boundary. $\theta = 30^\circ$.